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Estimating Historical Intrinsic Production Potential: Interior Columbia Stream Type Chinook and Steelhead Populations.

Goal: ***For each ESU population, characterize areas within freshwater tributary habitat with respect to the ability to support salmon or steelhead production based on natural characteristics.***

Overview

No consistent, direct estimates of historical (pre-settlement) production potential are available across interior TRT watersheds. The analysis described below is intended to provide a simple and objective overview of the distribution of production potential across the tributary habitats used by Interior basin stream type chinook and steelhead. The analysis is relatively coarse scale and is intended to be used in combination with more specific studies aimed at particular watersheds or basins.

The approach is patterned after analyses of the production potential of salmonids in other domains. The Puget Sound TRT developed an approach for estimating production potential (measured as spawners/unit length) from basic habitat measures - stream width (bankfull, m), stream gradient, valley width and vegetative cover. The approach relies on a relationship between salmon spawner densities and channel characteristics (Montgomery et al., 1999). Puget Sound chinook are generally ocean-type - migrating to salt water after a few months of rearing in freshwater. Similar sets of habitat measures have been used as the basis for map based approaches to estimating production potential for coho and steelhead in Oregon coastal watersheds (e.g., Nickelson et al. 1992; Burnett, 2001). Those methodologies incorporate derived relationships between the habitat characteristics and juvenile rearing capacity or relative survival.

With the exception of Snake River fall chinook, Interior Basin listed chinook and steelhead populations are predominately stream-type - rearing for a year or more in freshwater before migrating to the ocean as smolts. It is commonly accepted that rearing conditions during the summer after emergence and the following winter are key determinants of year class strength. For stream type chinook, there is evidence that habitat conditions supporting relatively high densities for rearing also support relatively high spawning densities. The following approach to estimating the intrinsic capacity assumes that summer and winter rearing habitat are the key factors determining the relative productivity of freshwater tributary reaches.

Steelhead and chinook salmon appear to be adapted to take advantage of different types of freshwater habitat. Both yearling and stream type chinook densities are typically highest in relatively low gradient, unconfined stream reaches with well defined pool structure (e.g., Hillman& Miller, 2002, Petrosky & Holubetz, 1988). Steeper gradient relatively confined tributary reaches typically support the highest relative densities of juvenile steelhead (e.g., Slaney et al., 1980, Petrosky & Holubetz,1988, Burnett, 2001). Steelhead have also been reported to use braided mainstem reaches for spawning and rearing, given appropriate flow, temperature and and substrate conditions (e.g., ODFW, 1972).

Steps:

1. Identify criteria for defining upper and lower boundaries to salmon/steelhead production in Interior Basin ESU watersheds.

2. Review available data sets relating simple measures of habitat characteristics to production potential for salmon and/or steelhead and select one or more habitat characteristics representative of high, low or moderate levels of fish productivity.

3. Develop or acquire GIS layers incorporating key habitat measures related to salmon and steelhead production potential for Interior Basin ESU populations.

4. For each population, assign spawning/rearing reaches with respect to salmon and steelhead production potentials - as high, moderate, low or none.

5. Aggregate and summarize production potential for salmon and steelhead by HUC-6 within each population.

Methods:

Upper and lower limits to salmon and steelhead production in Interior Basin freshwater tributaries were calculated using temperature and gradient measures. Upper limits to production of salmon and steelhead were defined in terms of stream width and gradient. Production was assumed to be absent from reaches with a bankfull width of less than 3 m. Reaches above gradient barriers were also excluded as production areas. Gradient barrier was defined as a slope of greater than 20% within a 200 meter reach. The lower reaches of many interior basin tributaries are subject to relatively high summer temperatures - well above levels injurious to salmon and steelhead. We adopted the temperature criteria used by Chapman & Chandler (2001) as a limit on salmon and steelhead production areas - reaches in which the weekly mean average temperature (WMAT) exceeded 22 degree C were rated as Primarily Migration with respect to production potential for salmon and steelhead. *Note: the initial set of variables used in this analysis do not reflect the effects of groundwater on ameliorating temperatures in mainstem reaches with broad, alluvial flood plains (e.g., lower Yakima).*

In the early to mid 1980's, IDFG biologists compiled a baseline data set for evaluating the effectiveness of habitat improvement projects. The data set included both measures of parr densities (chinook and steelhead/rainbow trout) and habitat measures. The study concluded that chinook parr densities were the highest in low gradient stream sections in relatively wide valleys and that steelhead/rainbow juvenile densities were the highest in steeper gradient, more confined reaches (e.g., Petrosky & Holubetz, 1988). Maximum parr densities were also influenced by sediment levels. The original analyses focused on data collected in years with relatively high parental escapements to minimize the confounding effect of relatively low seeding (Petrosky and Holubetz, 1988). We used data from naturally seeded areas from that parsed data set for the current analyses. For each species, parr densities were plotted against gradient and stream width within two valley width categories corresponding to B channel and C channel designations (Rosgen, 1985) used in the original study. Wider stream reaches known to be used for spawning and rearing by at least steelhead were not well represented in the Idaho baseline study. A second data set, compiled by the Washington Dept. Of Game for larger rivers in western Washington and Puget Sound, was also analyzed to provide some insight into production relationships in larger systems.

Criteria

Four different habitat measures were used to define a set of criteria for estimating reach specific production potential for stream type chinook and steelhead using interior Columbia basin tributary habitats. The four habitat criteria selected were stream width (estimated or measured as bankfull width), stream gradient (percent change in elevation over reach), valley width (relative width of valley associated with a stream reach) and riparian vegetation. Results from the analysis are summarized by species in Table 1.

Stream width (bankfull width) Four stream width categories were established based on an examination of the data sets - > 3m, 3 to 25 m, 25 - 50 m and >50 m. Streams less than 3 m in bankfull width were at the lower margins sampled in the Idaho baseline study and are assumed to be too small to support spawning and rearing of either species. The Idaho study reaches included few streams between 20 and 30 m in bankfull width. The WDG study included mainstems up to 50 m in width. Steelhead parr densities at gradients exceeding 1.0 remained at relatively high levels in the widest streams.

Valley width. The Idaho baseline study classified streams as B type or C type channels using criteria proposed by Rosgen (1985). Given the intent to develop criteria that could be applied using a GIS analysis, we developed a specific measure to use in defining a particular area as if valley width exceeded 20 times bankfull width at the midpoint of a stream segment it was classified as a C channel type. Streams characterized by bankfull width less than 100 m were treated in a separate category and assumed to be B type.

Gradient: A set of gradient categories was developed based upon the Puget Sound TRT chinook matrix (e.g., Table 2 in WRIA 18 Draft Summary Rept - Puget Sound Chinook Recovery Analysis Team) and the categories used in the Idaho and Washington Game Dept. studies. For chinook, most of the observed parr density/stream gradient data pairs fell within the 3 to 25 m streamwidth category (Figure 1). In general, densities were relatively high at gradients below 1.0 to 1.5 % gradients. Although observations were relatively sparse, densities were relatively low at gradients exceeding 1.5 to 2.0 percent. The frequency of samples exhibiting low pool cover (less than 50%) increased rapidly as gradients exceeded 1.5%. Steelhead/rainbow exhibited the reverse pattern with relatively low densities at gradients below 0.5, increasing as gradients increased to approximately 4% (Figure 2). Densities remained relatively high at gradients between 2% and approximately 10%. In the western Washington study, densities followed a similar pattern. *Note: reviewers have suggested considering incorporating a measure of the aquatic productivity of a watershed (e.g. based on lithology).*

Riparian vegetation: One additional modifier was incorporated into the framework based on the Puget Sound chinook example. Pool structure in Puget Sound was affected by the availability of large woody debris. It was not possible to evaluate the potential linkage with riparian cover with the Idaho parr density/habitat baseline data base. For the purposes of this study, we included the assumption that the availability of LWD from adjacent riparian areas (where designated as Mesic forest or similar classifications) would result in increased pool structure in moderate gradient reaches. *Note initial pilot studies do not include this as a modifier*.

Figure 1. Idaho Spring/Summer Chinook. *Juvenile densities vs stream gradient for naturally seeded baseline monitoring areas in the Salmon and Clearwater River systems. Parsed data set- low seeding years not included (Petrosky and Holubetz, 1988). Dotted lines indicate assigned category boundries.*

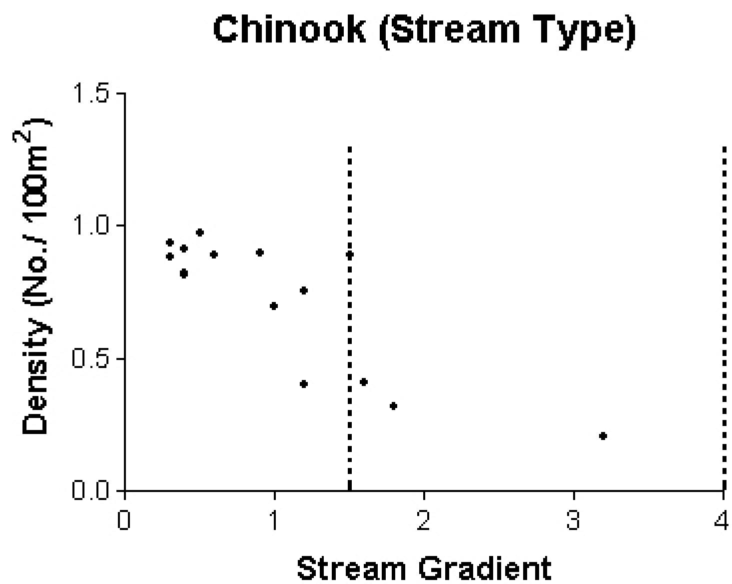


Figure 2. Idaho Steelhead. *Juvenile densities vs stream gradient for naturally seeded baseline monitoring areas in the Salmon and Clearwater River systems. Parsed data set- low seeding years not included (Petrosky and Holubetz, 1988). Dotted lines indicate assigned category boundries.*

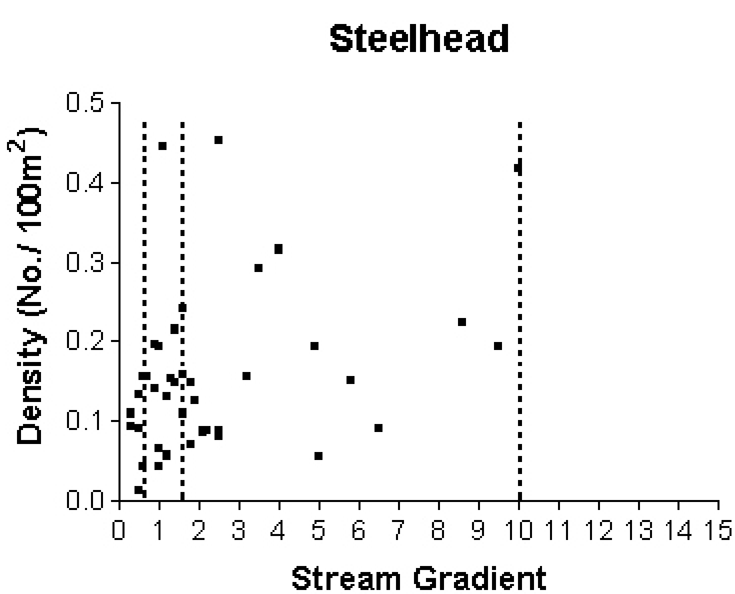


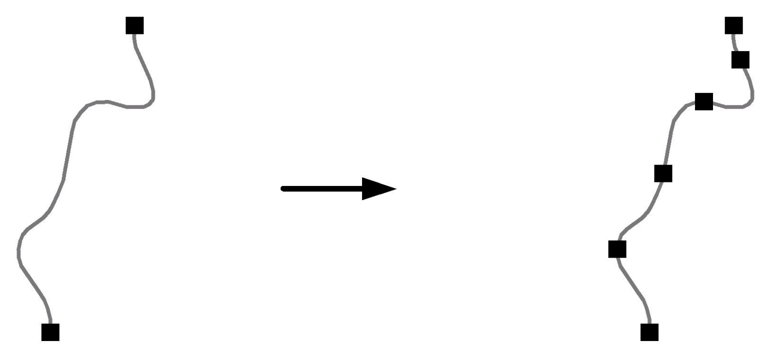
Table 1. Criteria for assigning tributary habitat stream reaches to productivity categories for yearling type chinook an steelhead.

Stream Width (Bankfull)	**Stream Reach Gradient**	**Valley Width Associated with Stream Reach**	**Steelhead Density Rating**	**Chinook Juvenile Density Rating**
Less than 3 m Bankfull width				
3 to 25 m Bankfull width	0.0 to 0.5	< 20 X Stream Width	Low	Medium
		> 20 X Stream Width	Low	**High**
	0.5 to 1.5	< 20 X Stream Width	Medium	**High (Mixed Forest)** Medium (Other Riparian)
		> 20 X Stream Width	Medium	**High**
	1.5 to 4.0		**High**	Low
	4.0 to 10.0		**High**	Primarily Migration
	> 10.0		Low	Primarily Migration
	>15.0		None	None
25-50 Bankfull Width	0.0 to 0.5		Low	Medium
	0.5 to 4.0		Medium	Low

Chinook and Steelhead Habitat Mapping

Three distinct habitat measures were generated and used to quantify intrinsic potential for Interior Columbia Basin spring chinook and summer steelhead populations: stream gradient, active channel width and valley width (relative confinement of stream). Various GIS data sets were used to determine these metrics for tributary habitats, the most important being digital elevation models and hydrographic themes.

A networked stream layer based on the National Hydrography Framework (NHD) 1:100,000 dataset was developed as a first step in the mapping exercise. Only natural hydrographic features were used, reaches obviously altered by anthropogenic activities such as ditches, drains and canals were removed for the analysis. Using ESRI's AVENUE programming language, a script was developed that compiled an output table containing each unique segment divided into 200 meter sections. Determination of this length metric was based upon previous studies which concluded that a 200 meter segment with a mean gradient of 20% would constitute a impassable migration barrier. Each segment was attributed with a unique "address" to be used for linear referencing with the NHD networked stream layer (figure 3). This methodology produced an end segment which was less than 200 m (StreamLength - (200 * n)), these were excluded from further analyses. Ultimately, over 500,000 individual segments were created within the Interior Columbia Basin ESUs using routed event theme processes.



Length	name
871.70	Rock Creek

Length	Fromd	Tod	name	address
200.00	0.00	200.00	Rock Creek	200 Rock Creek
200.00	200.00	400.00	Rock Creek	400 Rock Creek
200.00	400.00	600.00	Rock Creek	600 Rock Creek
200.00	600.00	800.00	Rock Creek	800 Rock Creek
71.70	800.00	871.70	Rock Creek	879 Rock Creek

Figure 3. Stream segmentation using linear referencing and route events.

Gradient was calculated by intersecting the stream segments with the digital elevation model (USGS 30 meter resolution) and dividing the change in elevation across a segment by the length of that segment. Assigning elevations to stream segments posed some significant accuracy problems. This was primarily due to the lack of spatial concurrence between the 1:100,000 stream layer and the 1:24,000 digital elevation models. The stream segments did not always match the flow paths inherited from the DEMs, so alternate methods were developed in order to correct this spatial discrepancy. Using principles of euclidean geometry, perpendicular cross-sections were created for all stream segments (figure 4) . These cross-sections were then analyzed using zonal statistics in order to find their corresponding minimum elevation (which could be assumed to be the center of the DEM generated flow). With the DEM flow path elevations known, a minimum and maximum value were then assigned to each stream segment and gradient values calculated. All stream reaches below those segments exhibiting a 20% gradient were assumed to be potentially accessible to chinook salmon and steelhead.

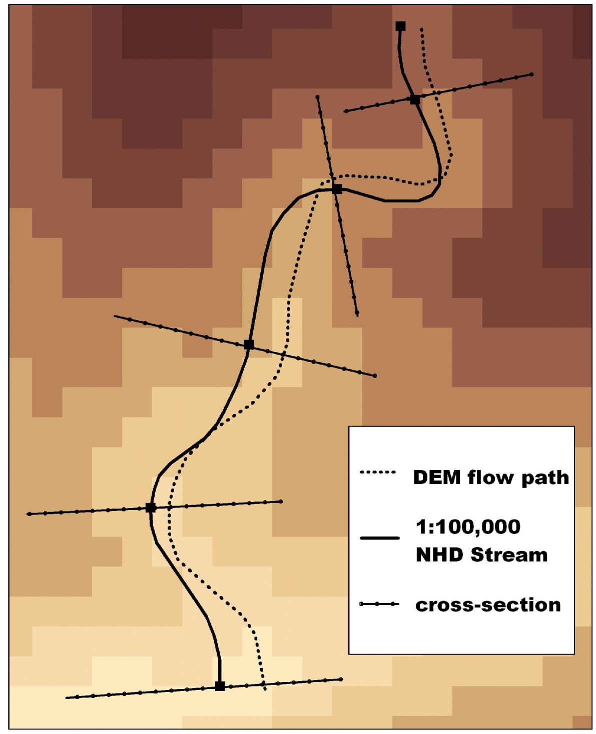


Figure 4. Spatial non-congruency between differently scaled features, with cross-sectional placement.

A simple model was developed and used for calculating channel width based on measures recorded in small scale habitat studies and photo interpretations. This methodology was built upon similar efforts undertaken by the Puget Sound TRT (Davies, Lagueux 2003). Measured widths (bankfull) were compared to basin area and accumulated precipitation using linear regression techniques. Analyses were conducted independently between major basins in order to ensure model effectiveness, and reduce the impact of potentially significant basin specific characteristics. The analyses indicated that the relationship of channel width to basin size and accumulated precipitation were highly significant and positive. The resulting regression models were applied to their respective watersheds and summarized by 200 m stream segments.

Valley width was the third variable calculated based on information in GIS data layers. Again, AVENUE was employed for coding automated scripts for spatial theme development. Flow paths from the DEM were isolated and their elevations were analyzed using euclidean allocation techniques in ArcView's Spatial Analyst. By subtracting the euclidean allocation theme from the original DEM, it was possible to create a theme showing the change in elevation between the stream (flow path) and the adjacent topography. For this analysis, a 3 meter change was used as a standardized metric for computing relative valley width. Once this portion of the analysis was complete, a buffer was developed for each unique stream segment. The percentage of the buffer that was occupied by the change in elevation theme served as a relative measurement for stream confinement and valley width (figure 5). For example, if 100 % of the buffer was filled, then the valley width would be at least as wide as the buffer, and the stream classified as unconfined.

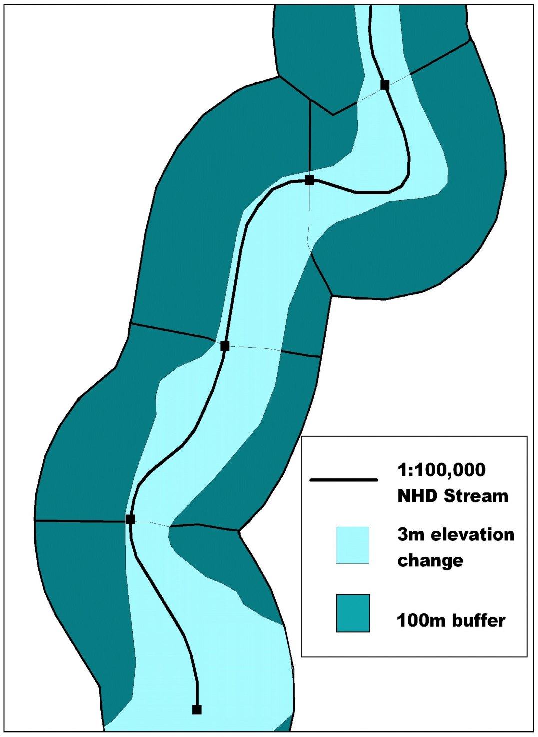


Figure 5. Graphic showing the area of the 100m buffer occupied by a 3m change in elevation.

Preliminary temperature analyses were also conducted for evaluating salmonid habitat. However, unlike the other variables, this was not applied directly to the rating of habitat quality but was instead used for defining the extent of thermal barriers and hence the downstream limit to smolt survivability. Building upon previous studies ( ), elevation, air temperature, and landcover type were used to develop regression equations for predicting maximum weekly mean water temperatures. The primary goal was to produce a contour showing where the maximum weekly mean was greater than or equal to 22°C. Initial analysis show that these relationships are significant, and that the delineation of thermal barriers may be possible.

Stream gradient, active channel width and valley width (confinement) were used to classify individual reaches relative to their potential for supporting chinook and steelhead rearing using the results of the mapping exercise and the species specific rule sets described in Table 1. Each segment was designated as “High ”, “Medium”, “Low” or “Primarily Migration” with respect to each species. The results were compiled by HUC-6 and by population for each ESU. Two sets of results were calculated for the pilot basins (the Grande Ronde and Yakima river systems) one set with streams designated (source layer cite??) as intermittent included and a second set with those streams removed from the analysis.

Results - Grande Ronde and Yakima Populations

Maps, Tables and Graphs

Discussion - including caveats.

Literature Cited

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